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DEPARTMENT OF DEFENSE HIGH PERFORMANCE COMPUTING MODERNIZATION PLAN

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13. ABSTRACT (Maximum 200 words)

In May 1992, the Secretary of Defense forwarded the DoD High Performance Computing (HPC) Modernization Plan to Congress. That plan, prepared by the Office of the Director of Defense Research and Engineering and published in March 1992, provided the rationale, process, timetable, and funding requirements for high performance computing modernization supporting DoD research, development, test, and evaluation. The purpose of this document is to update and revise the Modernization Plan to reflect the activities of the past two years, and to present FY94, FY95, and outyear plans.

The DoD HPC Modernization program is structured to modernize the total high performance computational capabilities of DoD research and development (R&D) to a level comparable to that available in the foremost civilian and other Government agency R&D environments. The program is multifaceted — creating robustly networked HPC environments at Major Shared Resource Centers, accommodating specialized HPC requirements at Distributed Centers, adapting and developing scalable applications software, and educating users as new architectures and concepts evolve. The program fosters meaningful interaction with the entire HPC community to facilitate sharing knowledge, tools, and expertise.

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DoD HPC Modernization Plan

Office of the Director of Defense Research and Engineering

Department of Defense

June 1994

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PURPOSE

In May 1992, the Secretary of Defense forwarded the Department of Defense (DoD) High Performance Computing (HPC) Modernization Plan to Congress. That plan, prepared by the Office of the Director of Defense Research and Engineering (DDR&E) and published in March 1992, provided the rationale, process, timetable, and funding requirements for high performance computing modernization supporting DoD research, development, test, and evaluation (RDT&E). The purpose of this document is to update and revise the Modernization Plan to reflect the activities of the past two years, and to present FY94, FY95, and outyear plans.

The DoD HPC Modernization program is structured to modernize the total high performance computational capability of DoD research and development (R&D) to a level comparable to that available in the foremost civilian and other Government agency R&D environments. The program is multifaceted—creating robustly networked HPC environments at Major Shared Resource Centers, accommodating specialized HPC requirements at Distributed Centers, adapting and developing scalable applications software, and educating users as new architectures and concepts evolve. The program fosters meaningful interaction with the entire HPC community to facilitate sharing knowledge, tools, and expertise.

SCOPE

This plan covers HPC in support of the DoD science and technology program under the cognizance of the DDR&E. It also stimulates interaction and coordination with other DoD and external R&D activities and promotes the incorporation of HPC technology into DoD operational environments.

Executive Summary

The Department of Defense relies on technologically superior systems to counter numerically larger forces, to reduce casualties and damage to the national infra-structure, and to permit rapid, decisive action when necessary. While DoD is facing significant reductions in force structure, the need to maintain technical superiority is more critical than ever. Therefore it follows that it is necessary to sustain the investment in Science and Technology (S&T) and the supporting key technology program—***the DoD High Performance Computing Modernization Program***.

The success of the HPC Modernization Program will critically impact the conduct of the Department's Science and Technology initiatives as it addresses the crucial next step of integrating and deploying advances in computing and communications into DoD S&T programs, and couples them with military systems design and development.

The DoD HPC Modernization Program is structured to modernize the total high performance computational capability of DoD research and development (R&D) to a level comparable to that available in the foremost civilian and other Government agency R&D environments. This is in consonance with the Congressional direction to DoD to program and budget for HPC modernization of its laboratories in recognition that the HPC resources and environments available to defense scientists and engineers had fallen below the levels available to their counterparts in the civilian sector.

The resultant DoD HPC Modernization Program is a coordinated, sustained initiative to develop complete, balanced HPC environments based on user requirements. The planned HPC capability is focused upon the establishment of networked Major Shared Resource Centers (MSRCs) and Distributed Centers. The MSRCs provide complete HPC environments including various types of computing systems, scientific visualization capabilities, extensive peripheral and archival storage, and expertise in use of these systems. The MSRCs support the wide variety of research and development problems arising from the S&T program. The MSRCs address the computer and computational sciences, and provide the education and training which allows all of the DoD laboratories to be more productive in S&T research and development. In addition to the MSRCs, the program will deploy systems at Distributed Centers to fulfill special R&D requirements where deployments of the HPC systems are critical to success of R&D efforts.

Initiatives and mechanisms are being established to ensure that the modernization of the DoD laboratories is interrelated, well formulated, and within the context of the national HPC infrastructure. The program will take actions to encourage and facilitate interactions, collaborations, and communications with the civilian HPC community and other government agencies to share knowledge, tools, and expertise.

The program is built upon the foundations of proper planning and management. The program vision, goals, strategies, and metrics are described herein in detail, and, with the requirements analysis (summary herein), form the basis for modernization decisions and acquisition plans/strategies. A Joint High Performance Computing Modernization Office was formed to function in an intellectual and leadership role for defining the direction, planning, and policy-making for DoD HPC Modernization. This office will perform the necessary life cycle management functions and the acquisition streamlining processes, as required, to implement and execute the program in an effective and cost efficient manner.

Finally, the plan identifies the current and following five year funding requirements to enable the ongoing DoD R&D activities to meet mission-driven requirements and to fully engage the national HPC computational and networking trends.

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1. Introduction

In March 1992, the Office of the Director, Defense Research and Engineering (DDR&E) published the Department of Defense (DoD) High Performance Computing (HPC) Modernization Plan. The purpose of the plan was to provide the rationale, process, timetable, and funding requirements for high performance computing modernization in DoD research, development, test, and engineering under the cognizance of the DDR&E. This document updates the DoD HPC Modernization Plan, reflecting the activities of the program to date, and the plans necessary to meet the Congressional modernization mandate. The document is structured to provide the reader with a review of DoD mission needs, the program genesis, and the recent program realignment. The plan then addresses the program foundations: vision, goals, strategies, and metrics. A summary of a recently completed comprehensive DoD HPC requirements analysis is provided, followed by the FY94, FY95, and outyear implementation plans to satisfy these requirements. Finally, the funding required to address mission-driven requirements is presented.

1.1 Mission Needs

The mission of this program is to modernize the high performance computational capability of DoD laboratories to a level comparable to that available in the foremost civilian and other Government agency R&D environments. The program is multifaceted. It involves creating HPC environments at major and distributed centers accessible to local and remote scientists and engineers via high-speed networks. Providing for the adaptation of existing and development of new scalable applications and algorithms to address growing science and technology requirements, along with continued education of users as new architectures and concepts evolve, are integral components of the program. The program pursues continuous interaction with the national HPC infrastructure, including academe, industry, and other government agencies to facilitate the sharing of knowledge, tools, and expertise.

High performance computing has been identified as a key enabling technology essential to achieving the objectives of the Department's science and technology (S&T) program. DoD intends to exploit the orders of magnitude improvements in computational and communications capabilities as a result of advancement in hardware, architectural designs, software, networking, and computational methods in support of DoD missions.

Many Defense-related problems in the areas of chemistry and materials science, computational fluid dynamics of air, undersea, and surface vessels and their ordnance, parametric weight/vulnerability reduction studies, automatic target recognition, submarine hydrodynamics, ocean acoustics, high performance weapons design, and prediction and dispersion of hazardous materials, require computational performance of trillions of operations per second (teraops). These diverse S&T applications also require massive data storage and scientific visualization capabilities to render the computational results in graphical images that enable understanding of the computations. The reliance of S&T research on computational science is increasing rapidly due to the greatly expanding use of HPC in scientific research, modeling, and simulation. HPC greatly benefits DoD laboratories by decreasing the need for prototype systems and limiting the amount of live-fire tests. Solutions to critical problems leading to advancements in these areas are fundamentally driven or limited by the HPC capability and environment within the Defense laboratories. DoD S&T researchers require HPC environments populated with a variety of system architectures and data storage to permit the highest fidelity and greatest speed in analyzing problems of ever increasing size and complexity.

For these reasons, it is critical that DoD vigorously continue implementation of this modernization plan. While some recent improvement has been achieved by the program, HPC systems currently available to most DoD users significantly lag behind those commercially available. Current data storage and scientific visualization capabilities are undersized and inadequate for today's research problems. Many science problems, modeling and simulation applications require HPC systems capable of scaling to several orders of magnitude in performance beyond those being used by DoD laboratories today. Software initiatives are needed in applications and algorithm development to enable use of the latest scalable technologies. Placement of these new technologies in the laboratories requires renewed emphasis on new software techniques, computational and computer science, and on education and training. All of these areas are fundamental to effective HPC capability and must be modernized and upgraded in parallel to meet even today's requirements of the DoD S&T community.

DoD will need to provide seamless HPC capabilities to scientists and engineers (S&E) throughout DoD regardless of location of resources. To support the requirements of remote users, an advanced high-speed, robustly interconnected network linking DoD S&T researchers to the advanced HPC systems is needed. This network capability will require continued advancement to remain consistent with the performance of the computing systems, the growing data traffic requirements, and rapidly evolving network technology.

Finally, to fully achieve the Department's scientific computational needs, applications, software tools, and algorithm development must be advanced and expanded to take advantage of the emerging computing power. The DoD HPC Modernization Program must stimulate the efforts of its own researchers and engage and leverage the efforts of academe and industry to improve the ability to effectively address HPC software problems.

1.2 Background

In 1991 Congress noted that DoD laboratories lagged considerably behind the Department of Energy (DOE), National Aeronautical and Space Agency (NASA), and National Science Foundation (NSF) Supercomputer Centers in computing capability. This prompted the enactment of language in the National Defense Authorization Act of FY92-93 directing DoD to present a five year master plan to Congress to modernize of the HPC capabilities of the DoD laboratories. The DDR&E established the HPC Working Group (HPCWG) to develop this plan. The HPCWG consisted of representatives from the Services, Defense Nuclear Agency (DNA), Advanced Research Projects Agency (ARPA), and the Office of the Assistant Secretary of Defense for Command, Control, Communications, and Intelligence (ASD(C3I)). The Secretary of Defense forwarded the original DoD HPC Modernization Plan to Congress in May 1992. A FY93 Implementation Plan and the HPC Modernization Program were initiated using funds that Congress had authorized and appropriated (FY92 ($42M) and FY93 ($45M)) for DoD laboratory HPC modernization.

During FY93 a large general purpose vector supercomputer, a Cray C916/512, was acquired and installed at the Army Corps of Engineers Waterways Experiment Station

(CEWES), Vicksburg, MS. In addition, the following six scalable parallel systems were installed or upgraded:

- Intel Paragon XP/S-15, Aeronautical Systems Center (ASC), Wright-Patterson AFB, Ohio
- Intel Paragon XP/S-25, Naval Command, Control and Ocean Surveillance Center (NCCOSC), San Diego, California
- IBM SP1, Maui HPC Center (MHPCC) (supporting the Air Force Maui Optical Station (AMOS)), Maui, Hawaii
- Kendall Square Research KSR1-256, Army Research Laboratory (ARL), Aberdeen Proving Ground, Maryland
- TMC CM-5 enhanced, Naval Research Laboratory (NRL), Washington, DC
- TMC CM-5 enhanced, Army High Performance Computing Research Center, (AHPCRC) University of Minnesota, Minneapolis, Minnesota

In the area of connectivity, a high speed wide area network was established by integrating and supplementing existing Army and Air Force supercomputer networks to create the Interim Defense Research and Engineering Network (IDREN). This network, illustrated in Figure 1, interconnects defense S&T users and DoD HPC resources and provides gateway connectivity to the Internet.

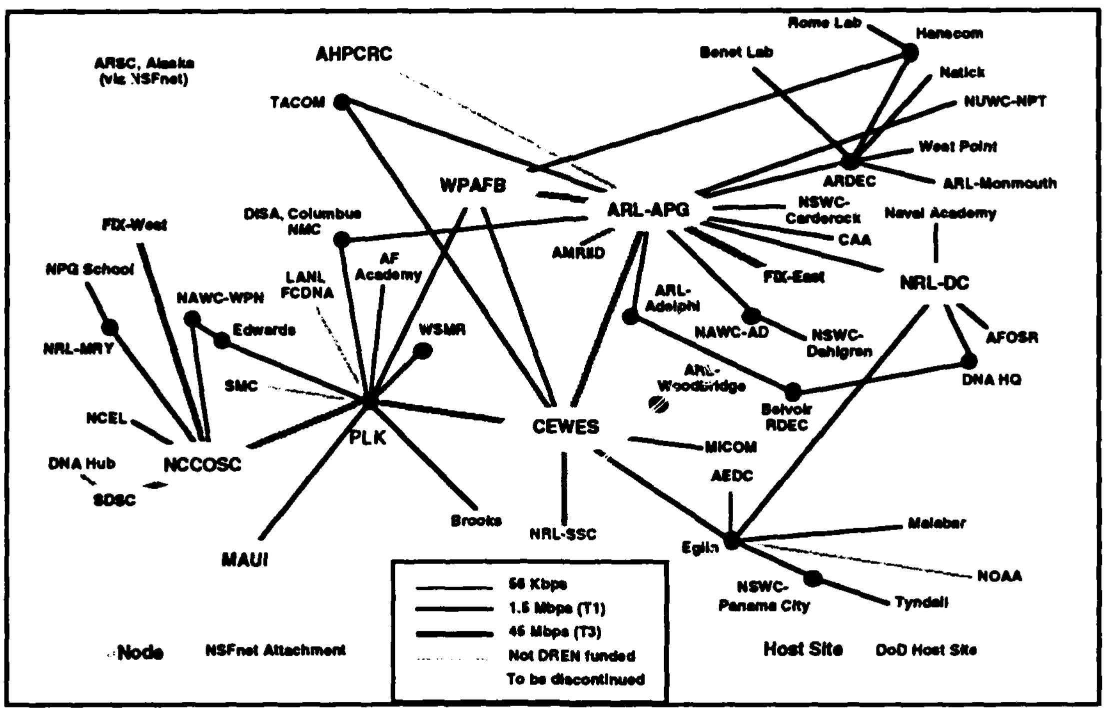

Figure 1. Interim DREN Configuration - 3Q FY94

Finally, during FY93, various upgrades were made to computing systems at the National Consortium for High Performance Computing (NCHPC) facilities. In return DoD was given access to NCHPC's computing resources and a Memorandum of Agreement (MOA) was put in place supporting DoD's HPC needs in applications software development The agreement defines six DoD technology thrust areas:

- Computational Structural Mechanics
- Computational Fluid Mechanics
- Computational Chemistry and Materials Science
- Computational Electromagnetics and Acoustics
- Climate / Weather / Ocean Modeling
- Signal / Image Processing

NCHPC will collaborate with the Modernization Program to accelerate the exploitation of scalable parallel systems to solve HPC problems in these technology areas. The MOA provides the DoD S&T community a training and information distribution infrastructure available through NCHPC and access for DoD researchers to NCHPC computers. NCHPC's MOSAIC information system will be used by DoD to access these NCHPC training and HPC resources, access to NCHPC HPC will facilitate DoD researcher collaboration with NCHPC academics and will allow scaling up to much larger scalable HPC in some cases.

1.3 Program Formalization

In recognition of the program's potential impact, magnitude of the effort, and the need for a more formal management structure, the DDR&E appointed an Executive Director and a Program Manager for the program in January, 1994. A HPC Modernization (HPCM) Office was created and staffed with representatives from each Service to review the program's vision and strategies to ensure that the program meets the laboratories' and R&D centers' long-term needs. The resultant program addresses the total HPC environment including both hardware and software issues. The HPCM office will continue to function in an intellectual and leadership role by defining the direction, planning, and policy for DoD HPC modernization. This office also performs the necessary life cycle management functions as required to implement and execute the program in an effective and cost efficient manner.

The high level management structure for the HPC Modernization Program is illustrated in Figure 2.

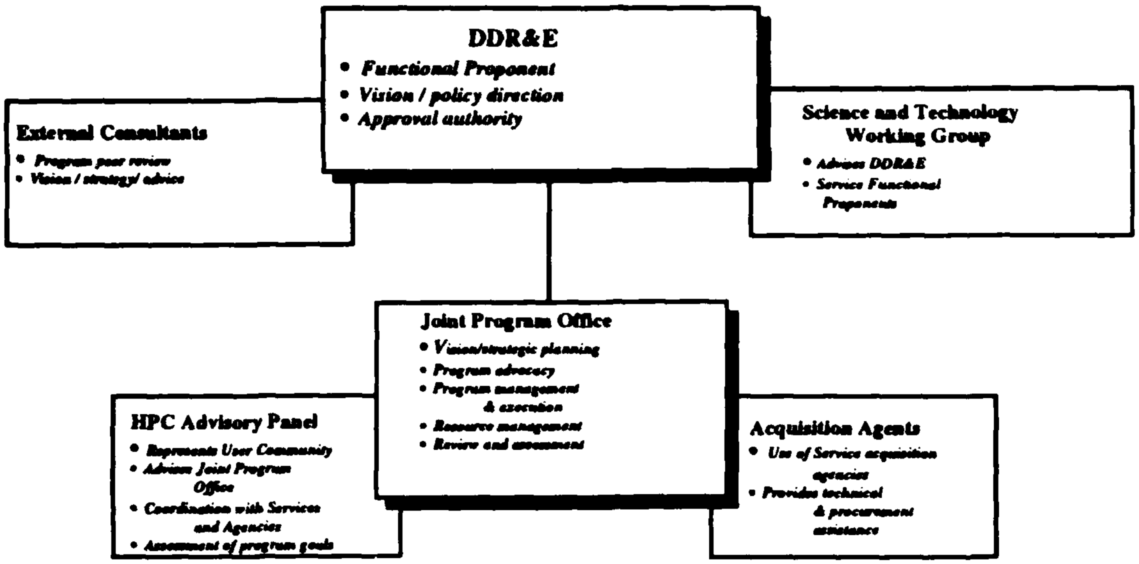

Figure 2. HPC Modernization Program Management Structure

2. Program Foundations

DoD HPC modernization is fundamentally driven by Defense S&T community requirements. This program will empower the DoD researcher to meet the computational challenges of the research and development (R&D) mission. To provide an integrated cost efficient solution, the modernization has been planned within the context of a set of guiding principles and precepts which can be termed vision, goals, program strategy, and metrics.

2.1 Vision

The HPC modernization vision is to raise DoD's R&D high performance computing and communications capacity and capabilities to a level equal to or greater than that available in the foremost academic research centers and industry, thereby enabling the United States to maintain its technological supremacy in weapon systems design and to foster the flow of this technology into warfighting support systems and dual-use functions.

Successfully fulfilling this vision means every DoD S&T researcher will have ready desktop access to the HPC tools necessary to complete the mission in a timely fashion. This implies that DoD researchers have access via their desktop systems to a broad HPC infrastructure which provides:

- Robust high-speed networking
- Remote classified and unclassified access through transparent network services
- A variety of powerful and easy to use systems and applications software to permit optimum mapping of system types to particular applications
- Massive, hierarchical data storage
- Immediate access to data
- Post-processing to facilitate meaningful data interpretation

2.2 Goals

The DoD HPC modernization program will strategically locate, rapidly deploy, and sustain the highest quality high performance computing environments and networks. The emphasis is on leveraging the national trends fostered by existing DoD investments in the Federal High Performance Computing and Communications (HPCC) Program, Defense HPC R&D, and other related research, development, test, and evaluation (RDT&E) efforts. It is a sustained program to fully engage and draw from the national effort.

Program initiatives are directed toward the following goals:

- Establish and improve the access to state of the art HPC capacity and capability for DoD scientists, engineers, and analysts to enable weapons development and more capable warfighting systems.

- Encourage development of software tools and applications to make it easier to use and exploit the capabilities of HPC, and expand and educate the DoD HPC user base.

- Engage, leverage, contribute to and be a major participant in the National HPC Infrastructure and exploit its benefits for Defense R&D. This engagement includes DoD laboratories, the Services' in-house basic research entities (Army Research Office, Air Force Office of Scientific Research, and the Office of Naval Research), the Advanced Research Projects Agency, industry, universities, and other Government agencies such as the Department of Energy, the National Science Foundation, and the National Aeronautics and Space Administration.

2.3 Strategies

True modernization of DoD's HPC capability and fulfillment of the above vision and goals requires a program strategy that addresses all aspects of HPC. While advancing the level of hardware performance is critical to success, the higher objective is to enable better scientific research and technology development for superior weapons, warfighting and related support systems.

The HPC assets acquired via this program will be available to scientists and engineers supporting the DoD S&T program in the Services and Defense agencies, as well as collaborative researchers in academe and U.S. industry supporting the S&T program. These HPC resources will be interconnected via the networking initiative being implemented under the DoD HPC Modernization Program, the Defense Research and Engineering Network (DREN). DREN will be interconnected to the Internet to allow DoD scientists and engineers to properly and adequately interface to their counterparts and colleagues in the civilian sector.

The strategy to improve availability and access to state of the art HPC capacity and capability encompasses:

- Providing a balanced set of HPC commercially available technologies to meet the full range of DoD requirements and to permit optimum mapping of requirements to system types.

- Building complete HPC environments at DoD laboratories and R&D centers designated as HPC Major Shared Resource Centers (MSRCs) to support the widest community of users. These MSRCs will include hardware, data storage, scientific visualization capabilities, high speed interconnections, supporting infrastructure, and expertise in computational and computer sciences and HPC software.

- Supporting development efforts designed to provide teracomputing capabilities and technologies which are applicable to Defense S&T requirements.

- Developing heterogeneous computing environments to allow the optimum mapping of varied S&T problems onto appropriate types of HPC systems.

- Provisioning, where appropriate, special configurations, designs, or architectures; embedded systems; classified systems; distributed data storage; or scientific visualization platforms at laboratories designated as Distributed Centers. These Distributed Centers will focus on and primarily address smaller scale, intense, local mission needs and also make unused capacity and capability available to remote users. In addition, Distributed Centers will allow leveraging of special collections of HPC expertise for the benefit of the entire program.

- Providing a focus on standards in DoD S&T software to ensure that future transitions and advancements in software technology are applied in an efficient and cost effective manner.

The strategy to encourage the development of software tools and applications and expand and educate the DoD HPC user base includes:

- Focusing on applications oriented software initiatives designed to overcome the technological inhibitors which delay the effective use of many scalable parallel high performance computers.

- Providing user education and training in computer and computational sciences, software applications and optimization, and code conversion.

- Promoting the formation of DoD-sponsored inter-disciplinary teams and collaboration groups to leverage academe and industry expertise in HPC for the solution of DoD problems.

- Deploying robust and cost effective network connectivity consistent with HPC traffic requirements among and between DoD researchers and HPC assets, and between the DoD and external R&D communities.

The strategy to engage, leverage, contribute to, and be a major participant in the national HPC infrastructure includes:

- Ensuring the Defense laboratories remain cognizant of, interact with, and leverage internal DoD HPC initiatives such as the ARPA technology development efforts and the algorithm and software research initiatives of the Defense research offices.

- Ensuring that the Defense laboratories, remain cognizant of, collaborate with, and leverage other government agencies' and each other's HPC efforts.

- Providing HPC environments to support defense applications which are directly related to dual use technologies and National Challenges, e.g., environment, medical, automotive, and manufacturing processes and products.

- Ensuring the availability of HPC environments to support Defense applications which address Grand Challenge needs, e.g., meteorological, oceanographics, and environmental modeling, nature of new materials, structure of biological and chemical phenomena, and energy efficient vehicles and airplanes.

2.4 Metrics

The metrics for this program are closely tied to the program goals. The ultimate measure of success will be improved quality of research within the S&T community, e.g. more realistic models and quicker solutions to DoD S&T problems. DoD R&D HPC capability and capacity will also be measured and compared relative to that available to the non-Defense HPC community. The success of the program in meeting this goal will be demonstrated by peer group evaluations.

In addition, the level to which DoD HPC capabilities satisfy the computational requirements of the S&T program will be monitored not only for computational speed, but also for all other HPC capabilities that are required for balanced HPC systems, such as central memory, secondary storage, and archival storage. The program's success in expanding and educating the DoD HPC user base will be measured qualitatively based on HPC use in Defense applications, while quantitative measures will be based on the increase in the number of new HPC applications and users. Success will also be measured qualitatively by user satisfaction with the training, ease of access, and ease of use of new or scalable systems. The metrics associated with the outreach program to engage and leverage the national HPC infrastructure will include the number of joint projects and collaborations with academe and industry, cooperative agreements that have HPC as a key factor, and evidence of transferred expertise and technologies to and from industry.

2.5 Outcomes

Deployment of modernized HPC provides an environment in which the DoD S&T community makes great strides using HPC to solve mission problems. Additional HPC resources allow researchers to tackle problems which are currently intractable. Improved HPC capability shortens design cycles by reducing the need to rely on hand-crafted prototypes and destructive testing. Robust, high-speed connectivity encourages daily collaboration among separated and remote users. Massive on-line hierarchical data storage coupled with interactive access to remote resources encourages users to ignore location and start considering hardware and software fit to a particular problem. Finally, lessons learned while executing the above provides important design feedback for future generations of improved HPC.

The broad DoD HPC system which is the logical result of this program will be widely recognized as a strategic resource. With these facilities, the DoD S&T community will routinely conduct world class research, and the knowledge and insights gained will be crucial to maintaining the technological edge the U.S. currently enjoys. In short, the environment created by this program will provide all DoD researchers the resources needed to successfully execute the S&T mission, and will empower each to access appropriate resources as needed without leaving his or her desk or workstation.

3. Leveraging National HPC Infrastructure

3.1 Program Relationships

The overall Defense investment in HPC consists of three interrelated initiatives: 1) participation in the Federal High Performance Computing and Communications (HPCC) Program, 2) Defense-specific HPC R&D programs, and 3) the DoD HPC Modernization Program. Each is a critically necessary element in the application of new HPC hardware and software technologies to Defense areas of science and technology that are essential to the development of new military systems. All three programs involve extensive ongoing research and development activities in academe and industry, as well as the Federal laboratories.

The Federal HPCC Program is a national commitment to HPC R&D and application of HPC technology to support the National Information Infrastructure. For complete details of the Federal HPCC Program see *High Performance Computing and Communications: Technology for the National Information Infrastructure*, a report by the Committee on Information and Communications, National Science and Technology Council.

The Defense-specific HPC R&D programs complement the Federal HPCC Program. These technology development programs focus on fulfilling Defense HPC needs such as providing tailored hardware or software elements, embedded systems, accelerators for specific problem domains, and other challenging Defense-specific problems. Planning for these programs is coordinated through the Office of the Director, Defense Research and Engineering (DDR&E) and through the Joint Directors of Laboratories Project Reliance infrastructure.

The HPC Modernization Program is a sustained activity designed to deploy high performance computing systems and networks at selected Defense laboratory locations to provide complete HPC environments that will enable Defense scientists and engineers to conduct important computational S&T in an effective and efficient fashion. The program will leverage technology, applications, computer systems, and software products developed directly or indirectly from DoD investments in the Federal HPCC Program, Defense-specific HPC R&D, and other R&D efforts.

With the Federal HPCC Program and Defense HPC R&D programs providing the techniques and the HPC Modernization Program providing the tools and environments, the Defense technology base programs will be significantly enhanced. In turn, these technology base programs develop the Defense-related areas of S&T that are critical to the development of new military systems.

3.2 The Federal HPCC Program

The goal of the Federal HPCC Program is to accelerate the development of future generations of high performance computers and networks and the use of these resources in the Federal Government and throughout the American economy. Scalable high performance computers, advanced high speed computer communications networks, and advanced software are critical components of a new National Information Infrastructure (NII). This infrastructure is essential to our national competitiveness and will enable us to strengthen and improve the civil infrastructure, digital libraries, education and lifelong learning, energy management, the environment, health care, manufacturing processes and products, national security, and public access to government information.

Specific program goals include:

- Extend U.S. technological leadership in high performance computing and computer communications.
- Provide wide dissemination and application of the technologies to speed the pace of innovation and to improve the national economic competitiveness, national security, education, health care, and the global environment.
- Provide a key part of the foundation for the National Information Infrastructure and demonstrate selected NII applications.

The goals will be realized through five equally important, integrated components representing key areas of high performance computing and communications:

- High Performance Computing Systems (HPCS) to extend U.S technological leadership in high performance computing through the development of scalable computing systems, with associated software, capable of sustaining at least one trillion operations per second (teraops) performance.
- National Research and Educational Network (NREN) to extend U.S. technological leadership in computer communications by a program of research and development that advances the leading edge of networking technology and services.
- Advanced Software Technology and Algorithms (ASTA) to demonstrate prototype solutions to Grand Challenge problems through the development of advanced algorithms and software and the use of HPCC resources.
- Information Infrastructure Technology and Applications (IITA) to demonstrate prototype solutions to National Challenge problems using HPCC enabling technologies.
- Basic Research and Human Resources (BRHR) to support research, training, and education in computer science, computer engineering, and computational science, and enhance the infrastructure through the addition of HPCC resources.

HPCC program strategies include developing the networking technology required for deployment of nation-wide gigabit speed networks through collaborations with industry; demonstrating the productiveness of wide area gigabit networking to support and enhance Grand Challenge applications collaborations; providing and encouraging innovation in the use of high performance computing systems and network access technologies for solving Grand Challenge and other applications by establishing collaborations to provide and improve emerging software and algorithms; and creating an infrastructure, including High Performance Computing research centers, networks, and collaborations that encourage the diffusion and use of high performance computing and communications technologies in U.S. research and industrial applications.

3.3 Defense HPC R&D Programs

The Advanced Research Projects Agency is the lead DoD agency for advanced technology research and development and has the leadership responsibility for the Federal HPCC Program within DoD. The ARPA program is developing the technologies needed to enable a broad base of applications and users on new scalable computing systems. In addition, the foundations for future generations of computing systems are being developed.

In the past year, the National Security Agency (NSA), has joined the HPCC Program. The goal of NSA's HPCC Program is to accelerate the development and application of the highest performance computing and communications technologies to meet national security requirements.

The three Services each have basic research efforts and HPC-related areas to address fundamental HPC research problems. These are addressed through the Army Research Office, The Office of Naval Research, and the Air Force Office of Scientific Research.

The Army Research Office (ARO) has efforts in computational methods performed by three categories of investigations: (i) single investigators, (ii) block efforts and (iii) Centers. The single investigator studies vary from scalable software tools for adaptive scientific computation to studies in elastodynamics. The block efforts are funded primarily by ARPA and deal with software development for scalable efforts.

The largest of the ARO-sponsored centers, the Army High Performance Computing Research Center (AHPCRC) at the University of Minnesota, consists of three integrated functions, namely, (i) interdisciplinary research into various aspects of HPC including advanced algorithms, applications, implementation environments, and graphics and visualization; (ii) evaluation of advanced computing systems; and (iii) an infrastructure support program of structured technology transfer. A major emphasis is placed on human resources with significant emphasis on the involvement of Historically Black Colleges and Universities and Minority Institutions (HBCUs/MIs).

The Office of Naval Research is sponsoring a five year (FY93-97) multidisciplinary basic research initiative in massive parallelism with the goal of concurrently accelerating computational research capabilities in Navy-critical application domains while using the characteristics of these applications to drive research in advanced system software support, programming environments, and numerical methods. The initiative focuses on three specific application domains chosen for their mission criticality and the spectrum of challenges they offer to scalable parallel computing: large-scale ocean circulation simulation, atomic and molecular interaction calculations for advanced materials, and solid-phase propellant combustion. Many of these applications exhibit irregular, dynamic, or adaptive behavior inadequately supported by existing parallel programming methodologies resulting in codes that lack efficiency, scalability, or portability. Expected results include efficient, scalable, portable codes representative of the three target application domains; prototype compilers, programming tools, and system software; and innovative parallel numerical algorithms. Transition plans include widespread distribution of prototype software and algorithms and possible installation of prototype software at DoD HPC Major Shared Resource Centers.

Also, the Office of Naval Research manages a development program to explore HPC applications enabling solution of real Navy problems. For example, completed tasks have investigated applications to (1) increase range/depth/azimuth resolution from passive sonar arrays, (2) perform 2D and 3D visualization of geographic data on a massively parallel SIMD architecture, and (3) accomplish the parallelization of a C3I mission-planning tool onto a heterogeneous computer array. Additional work is ongoing to investigate a number of Navy HPC applications.

Many of the future Air Force requirements for HPC require not only vast amounts of computational power, but they also require the development of vastly improved numerical methods to ensure that the application of this computational power achieves accurate answers to pressing problems. The Air Force program, primarily through the Air Force Office of Scientific Research (AFOSR) support in its external program to academia, concentrates on the development of these novel methods. AFOSR concentrates on supporting innovative methods and algorithms which enable the improved modeling, simulation, understanding, and control of complex physical phenomena.

The progress from AFOSR research efforts is utilized to impact critical applications areas, such as computational plasma physics, computational electromagnetics, computational fluid dynamics, and computational chemistry. In each of these application areas, the Air Force, through the AFOSR basic research program and other technology base support, manages an integrated extramural and in-house laboratory program to exploit the potential of high performance computing.

3.4 Other Government Agency Programs

Many other government agencies, such as DOE, NASA, and NSF, have extensive HPCC programs. DoD laboratories interact directly with these agencies and, in addition, the HPC Modernization Program plans to interact more directly with these agencies within its various program components. As the Modernization Program strives to provide a complete HPC environment to the users in the DoD S&T community, it recognizes that expertise in these various agencies can make vital contributions to that environment. Indeed, collaborative interactions currently exist among the DOE National Laboratories, the NSF HPC Centers, and DoD laboratories, including joint efforts in applications software development. Several DoD laboratories are members of consortia involving Non-DoD laboratories. The Modernization Program will leverage that expertise through a variety of cooperative HPC programs.

4. Requirements Analysis

The DoD HPC Modernization Program is designed to meet user requirements. In April 1994, a comprehensive Requirements Analysis was completed by the HPC Modernization Office, resulting in a requirements database that is being maintained to provide the primary basis for future program planning.

4.1 Methodology

This Requirements Analysis used information gathered via a survey and interview process with the functional user community. It was accomplished by a tri-Service team of eight scientists and engineers associated with HPC, with technical support from the Institute for Defense Analyses.

Table 1 lists organizations and locations that were determined to have *S&T HPC* requirements. The total numbers of HPC S&T users within the Services and participating Agencies are given in Table 2. Other agencies, such as the Defense Mapping Agency, have expressed interest in stating future requirements and will be included as requirement are periodically updated.

The analysis determined functional S&T requirements and all aspects of HPC requirements that resulted from these functional S&T requirements, including hardware, software, networking, and training. A major feature of the analysis was the exploration of how computational requirements flow from the underlying S&T program goals, and, in particular, to determine possible major accomplishments resulting from the exploitation of HPC capabilities. An important aspect of this activity is the determination of the impediments to routine use of new scalable HPC technologies by the DoD S&T program and methods for removing these impediments.

The DoD computational S&T program was categorized into nine technology areas. These areas are outlined, along with definitions of their scopes, in Table 3. The first six areas represent collaboration groups between the DoD computational S&T community and the National Consortium for High Performance Computing (NCHPC), designed to accelerate the productive use of new scalable HPC technologies by the DoD S&T program. The additional three areas were identified in the Requirements Analysis as distinct major DoD computational technology areas.

The quantitative and qualitative information was captured in a data base for display and analysis and to enable the program to assess the evolving requirements. Overall HPC performance requirements were aggregated in units of gigaflops-years (GF-yrs), i.e., one GF-yr is the computational capacity represented by a one GF processor computing for one year. In cases where user requirements were specified in terms of specific HPC systems, these requirements were converted to GF-yrs using vendor-provided theoretical peak performance for each of those systems. Recognizing that actual efficiencies vary widely from system to system and from application to application, use of theoretical peak performances to make the conversion to GF-yrs is considered to be more consistent and less arbitrary than development of subjective efficiencies for typical DoD applications.

Table 1. DoD S&T Sites

Organization	Locations
Army Research Laboratory	Aberdeen Proving Grounds (APG), MD Adelphi, MD Fort Monmouth, NJ Watertown, MA White Sands, NM
Tank-Automotive Research, Development, and Engineering Center	Warren, MI
Army Corps of Engineers	Champaign, IL Ft. Belvoir, VA Hanover, NH Vicksburg, MS
Missile Command	Huntsville, AL
Army Medical Research Development, Acquisition and Logistics Command (Provisional)	APG, MD Frederick, MD Walter Reed, MD
Army Research Office	Research Triangle Park, NC
Aviation and Troop Command	Moffett Field, CA St. Louis, MO
Concepts Analysis Agency	Bethesda, MD
Army Materiel Systems Analysis Activity	APG, MD
Armament Research Development and Engineering Command	Dover, NJ Watervliet, NY
Edgewood Research, Development, and Engineering Center	APG, MD

Organization	Locations
Naval Surface Warfare Center	Carderock, MD Dahlgren, VA
Naval Air Warfare Center	China Lake, CA Patuxent River, MD Warminster, PA
Naval Command, Control and Ocean Surveillance Center	San Diego, CA
Naval Research Laboratory	Monterey, CA Stennis Space Center, MS Washington, D.C.
Naval Undersea Warfare Center	Newport, RI
Office of Naval Research	Arlington, VA
Air Force Office of Scientific Research	Bolling AFB, DC USAF Academy, CO
Wright Laboratory	Eglin AFB, FL Tyndall AFB, FL WPAFB, OH
Rome Laboratory	Griffiss AFB, NY Hanscom AFB, MA Edwards AFB, CA
Phillips Laboratory	Hanscom AFB, MA Kirtland AFB, NM
Armstrong Laboratory	Brooks AFB, TX Tyndall AFB, FL
Defense Nuclear Agency	Alexandria, VA

Table 2. Total Number of HPC S&T Users

Organization	User Groups	Users
Army	60	1,595
Navy	93	757
Air Force	76	584
DNA	4	330
Total DoD	233	3,266

Table 3. Computational Technology Areas

Area	Description
1. Computational Structural Mechanics	• High resolution multi-dimensional modeling of materials and structures subjected to a broad range of impulsive loading ranging from weak to intense. • DoD application areas include conventional underwater explosion and ship response, structural acoustics, coupled field problems, space debris, propulsion systems, structural analysis, total weapon simulation, lethality/survivability of weapon systems (aircraft, ships, submarines, tanks), theater missile defense lethality analysis, and optimization techniques.
2. Computational Fluid Dynamics	• Detailed, three-dimensional, high resolution Navier-Stokes and large eddy simulation (LES) modeling of fluid flow for transport and tactical aircraft at transonic through high supersonic velocities, projectiles and missiles at subsonic through hypersonic velocities, and simulated nuclear and conventional weapon blast wave impact on tactical vehicles and structures. • Transient detailed reactive flows in two and three dimensions for engine and combustor design, chemical-acoustic instability and noise control, gun tube propellant modeling which includes multiphase flow, combustion of solid and liquid propellants, and detonation and explosion dynamics for safety, survivability, and lethality. • Detailed, three-dimensional transient hydrodynamic and airwake flow about ships, submarines, and torpedoes including the multiphase flows associated with cavitation, wavebreaking, and underwater explosions. • Detailed, medium and high resolution two- and three-dimensional incompressible flow modeling for investigating navigable waterway/harbor design, vessel/fluid and structure/fluid interactions, ship-to-shore logistics, hurricane protection, and hydrologic systems impacts on battlefield mobility. • Area includes atmospheric modeling, contaminant transport modeling for battlefield and environmental applications, and modeling of the cardiovascular system in humans, including blood flow through the heart.

Table 3. Computational Technology Areas (Continued)

Area	Description
3. Computational Chemistry and Materials Science	• Prediction using advanced computational chemical and molecular design tools to obtain accurate values of detectable spectroscopic properties, evaluate mechanical properties of proposed advanced materials, and evaluate the catalytic performance of zeolites and other catalytic materials for destruction of hazardous materials, such as halons. • Modeling of molecular and electronic structures, reaction pathways and dynamics, and intramolecular and intermolecular interactions of complex chemical systems. • Global optimization of extended molecular systems.
4. Computational Electromagnetics and Acoustics	• High resolution multi-dimensional solutions of Maxwell's equations to define the magnetic fields about shipboard antenna arrays, and the electromagnetic (EM) signatures of tactical ground and air vehicles, electromagnetic performance and design factors for EM gun technology, and electromagnetic signatures of buried munitions. • High resolution multi-dimensional solutions of the acoustic wave equations in solids, liquids, and gases to model the acoustic fields of bodies of water for underwater surveillance and communications, the seismic fields of soil for mine detection, and the acoustic shock waves of explosions for anti-personnel weapons.
5. Climate/Weather/Ocean Modeling	• The modeling of the earth's climate and weather aimed at improved prediction capability. • The modeling of various properties of the ocean (e.g., temperature, salinity, currents) to improve the processing gain for acoustic anti-submarine warfare (ASW).
6. Signal/Image Processing	• The extraction of useful information from sensor outputs (sonar, radar, imaging, signal intelligence (SIGINT), navigation), in real time. • Usually such processors are aboard deployable military systems and hence require ruggedized packaging and minimum size, weight, and power. • Also the research, evaluation, and off-line test data processing for these applications.
7. Forces Modeling and Simulation/C^4I	• The use of command, control, communications, computers, and intelligence (C^4I) resources to manage a battle space. • Faster-than-real-time large-scale simulations of complex military engagements to facilitate mission rehearsal, mission planning, and post-mission analysis. • Collaborative planning/replanning to support real-time operation decision-making.

Table 3. Computational Technology Areas (Concluded)

Area	Description
8. Environmental Quality Modeling and Simulation	• High resolution three-dimensional Navier-Stokes modeling of hydrodynamics and contaminant and multi-constituent fate/transport through the aquatic and terrestrial ecosystem and wetland subsystems, and their coupled hydrogeologic pathways, and their interconnections with numerous biological species. • Used for stewardship and conservation of natural and cultural resources, optimal design and operation of installation restoration, and enhancement alternatives and development of short- and long-term strategies for integrated management in support of installation environmental quality. • Work in the area of noise evaluation and abatement as well as water quality models.
9. Computational Electronics and Nano-electronics	• Simulation of electronic devices in circuitry, including fault simulation. • Monte Carlo and nonlinear quantum transport characterization in nanoelectronic devices. • Electronic structure calculations of novel materials for electronics applications.

4.2 Summary of Requirements Analysis

The DoD science and technology program has a large number of functional requirements which can be satisfied by rapid increases in HPC capabilities. These functional S&T requirements have been identified both as a set of grand challenge problems spanning the nine computational science technology areas and as the S&T goals of each individual DoD laboratory location. These functional S&T requirements result in overall HPC performance requirements for FY94, FY96, and FY99 as summarized by Service in Tables 4 and 5.

Table 4. Summary of Overall *Unclassified* Performance Requirements (GF-Yrs)

ORGANIZATION	FY94	FY96	FY99
TOTAL ARMY	297	3,829	27,119
TOTAL NAVY	138	1,196	15,679
TOTAL AIR FORCE	180	2,032	19,668
TOTAL DNA	1	1	2
TOTAL	616	7,058	62,468

Table 5. Summary of Overall *Classified* Performance Requirements (GF-Yrs)

ORGANIZATION	FY94	FY96	FY99
TOTAL ARMY	21	266	1,735
TOTAL NAVY	5	25	158
TOTAL AIR FORCE	16	266	3,021
TOTAL DNA	0	0	0
TOTAL	42	557	4,914

Each Service has rapidly increasing requirements for HPC capability in its S&T program over this five-year time period. As modeling and simulation activities play an increasingly larger role in DoD's R&D program, driven by the need to maintain technological superiority in this downsizing era, it becomes crucial that advances in HPC capabilities are rapidly made available to the DoD S&T computational community. As the tables indicate, the computational S&T community has significant requirements for and is ready to use teracomputing capability and beyond within the next five years to advance the S&T programs identified in this report so that DoD can maintain its superiority in warfighting systems.

The Requirements Analysis has confirmed the need for a full range of HPC system sizes, with users citing requirements from workstations, to clusters, to scalable parallel systems, to conventional supercomputers to accomplish their S&T computational mission. To use the high-end systems to their maximum effectiveness, many users require a variety of individual and clustered systems to pre- and post-process large production computations performed on the high-end systems. There is a common need for scientific visualization systems to allow scientists and engineers to make effective use of computational results. Providing a range of system sizes ensures that scientific and engineering problems of varying sizes can be accomplished on the most appropriate system, thus preserving high-end system resources for the largest problems.

It is widely accepted that no single architecture or system type will fulfill all of the computational requirements of the DoD S&T program. Systems that provide significant growth capability are essential to satisfying the rapidly growing computational S&T requirements identified in the Requirements Analysis.

A comparison between Tables 4 and 5 clearly shows that the bulk of the HPC requirements of the DoD S&T program is unclassified. The classified requirement is probably understated, however, due to the scarcity of available classified HPC resources at this time. Many scientists and engineers tend to compute problems that are unclassified and use those results to extrapolate, when necessary, to actual systems whose attributes are classified. Even though overall performance requirements for classified S&T computing are a relatively small fraction of the total requirement, those classified requirements represent a key ability for DoD to respond quickly in any time of crisis to developmental and operational needs.

In addition to computational capabilities, other key hardware requirements such as central memory, secondary storage, and archival storage were gathered and analyzed. A requirement for very large central memory, secondary, and archival storage was validated for any mode of operation of a large HPC system, whether it be to provide maximum throughput for a large number of DoD S&T users representing a broad mix of jobs, or to facilitate a limited number of very large grand challenge DoD S&T applications. Archival storage requirements will quickly expand to petabytes (10^{15} bytes) as more complex computational problems are attacked, with resultant increase in output file size. Automated storage capabilities are essential to ensure timely access to data for the large and growing computational S&T user base. Anticipated leaps in computational power will be essentially wasted if these central memory, secondary storage, and archival storage capabilities do not keep pace.

Software requirements were identified as the one key element in ensuring that DoD computational scientists and engineers would be capable of taking full advantage of the vastly increased computational capabilities of new scalable architectures. It is essential that mature operating systems and system tools be made available as soon as possible in a new system's life cycle so that its capabilities can be fully exploited. In addition, robust parallelization tools will help ensure compatibility of applications codes across different computational platforms. These parallelization tools include new standard compilers, debuggers, performance monitors, and other parallelization aids. One promising method of accelerating the transition of existing DoD applications codes to new scalable architectures is teaming computer scientists with an expertise in parallel programming with DoD computational scientists who are knowledgeable about the computational problems being addressed. In general, most computational scientists express a strong desire not to be computer scientists, but to spend their time doing S&T in the field of their training. This teaming would enable the development of expertise in the exploitation of scalable systems within the DoD S&T program, and could be facilitated by placing graduate and postdoctoral students and other temporary personnel with such expertise from academic computer science departments into DoD laboratories.

Networking is a critical ingredient in the overall ability to ensure accessibility to state-of-the-art HPC capabilities across the entire DoD computational S&T program. It is clear that every DoD S&T site will not be hosting a major HPC system and most sites will necessarily access the high-end systems remotely. The data gathered in the requirements survey indicate high performance and comprehensive networking capabilities are required to support effective, remote use of HPC resources. A prevalent and preferred mode of remote processing is to return all or most output data files to the local S&T site, enabling, for example, postprocessing and visualization rendering. These output data files are typically quite large and create large network throughput demands if timely transfers are to be achieved. Additionally, an eventual goal of real-time, interactive visualization performed on remote major resource center assets will require gigabit/second network bandwidth end to end. Postprocessing output data files at local S&T sites further introduces a requirement for large capacity archival storage resources at these local sites. A distributed data storage architecture, enabled by an effective high performance network, has the benefit of reducing long-term storage demands at the Major Shared Resource Centers.

To take advantage of projected Defense Research and Engineering Network (DREN) capabilities to meet these large networking requirements between Major Shared Resource Centers, Distributed Centers, collaboration partners, and user sites, each site must establish and support a local networking infrastructure capable of interfacing with DREN wide area services and be appropriately scaled to handle DREN-supported data rates. These local networking capabilities are the responsibility of each local site and failure to support an adequate local infrastructure will impede its scientists and engineers in their efforts to exploit DoD HPC resources to their full potential.

A final and critical aspect of networking is a classified capability. Classified S&T computing represents a key DoD capability to respond quickly in times of crisis. Current encryption technology severely lags network bandwidth performance and hampers the ability of the DoD Modernization Program to provide remote, high performance classified HPC capability. Until this encryption performance deficiency is resolved, there will continue to be critical classified HPC requirements which can only be met in the near-term with local classified resources. As part of the DREN initiative, developments in advanced encryption technology will be closely monitored and earliest possible deployment of approved products are planned.

Training and education requirements likewise focus on efficient use of new scalable HPC architectures. These requirements include specific HPC systems and efficient parallel programming techniques in general. Long-term, full-time programs will be necessary to provide training and education in the use and programming of scalable systems. Requirements also exist, but to a lesser extent, for systems software such as Unix, Fortran, Ada, and C, and for effective use of applications codes. For all training and education, a two-tiered system seems most effective: an introductory level for novices and an advanced level for more experienced users. Most users prefer training that is provided in their local areas, but recognize the need for a critical mass to ensure the cost effectiveness of that training.

The overall conclusion is that a complete HPC environment must be provided to take full advantage of HPC capabilities within the DoD S&T program. This environment must include a variety of HPC systems to provide the proper computational platforms for which computational problems will run most efficiently. Raw computational capability must be balanced by a compatible central memory, secondary storage, and archival storage capability. Systems software and efficient applications software must be available to allow the DoD scientist and engineer to compute effectively on HPC platforms and thus perform the DoD S&T mission. Special programs to accelerate the porting and development of applications software to fully utilize new scalable architectures are essential for the S&T computational program to stay abreast of new HPC capabilities. A reliable high-speed network is the crucial link between computational scientists and engineers at DoD laboratories and the high-end HPC resources located at DoD Major Shared Resource Centers. Training and education is essential to keep the user base technically current.

5. Implementation Strategy

5.1 Consolidation of DoD's HPC Infrastructure

The planned HPC infrastructure will consist of both centralized HPC resources located at MSRCs and decentralized HPC resources located at Distributed HPC Centers. As discussed earlier, these resources will be available to S&T researchers and engineers throughout the DoD laboratories and R&D centers via DREN. The roadmap/timetable for advancing the capabilities of this infrastructure is depicted in Figure 3.

Efforts conducted in FY93 and FY94 represent initial steps in advancing the HPC capabilities in the infrastructure. Providing a large Cray C90 system at CEWES in FY93 represented the first step in establishing a MSRC. Providing other laboratories and centers with new scalable systems and upgrades to existing scalable systems in FY93 was the first step in establishing Distributed HPC Centers. Establishing the Interim DREN by integrating the existing Army Supercomputer Network and the Air Force Supercomputer Network, and linking them to Navy and DNA centers, initiated the sharing of these HPC resources across all the Services and participating agencies. This action began the replacement of individual Services' and Agency's HPC centers with a consolidated DoD HPC infrastructure.

In FY94 these actions are continued with the initiation of an additional MSRC and several new Distributed HPC Centers, as well as upgrades to the first MSRC and some of the existing Distributed Centers. The major efforts to initiate the long term strategy will be conducted in FY95 and continued in FY96 and beyond. These actions are described in more detail in the following sections.

5.2 FY93 Efforts

Section 1.2 outlined the actions taken to provide additional HPC capabilities to the DoD S&T community as approved in the FY93 Implementation Plan using the combined funds provided by Congress in FY92 and FY93. Those actions have made significant enhancements to the DoD S&T program and have begun to satisfy the DoD S&T computational requirements as summarized in Chapter 4.

The addition of the Cray C916/512 and the conversion of the existing Y-MP8 at CEWES to DoD operations represents approximately a doubling of the vector HPC capability previously available to the DoD S&T program. While its overall HPC performance (16 GF-yrs) is only a small fraction of the 616 GF-yrs unclassified HPC requirements for FY94 stated in Table 4, it has allowed DoD researchers to attack significantly larger problems than they could previously. One crucial limitation has been the amount of central memory, secondary storage, and archival storage available on that system.

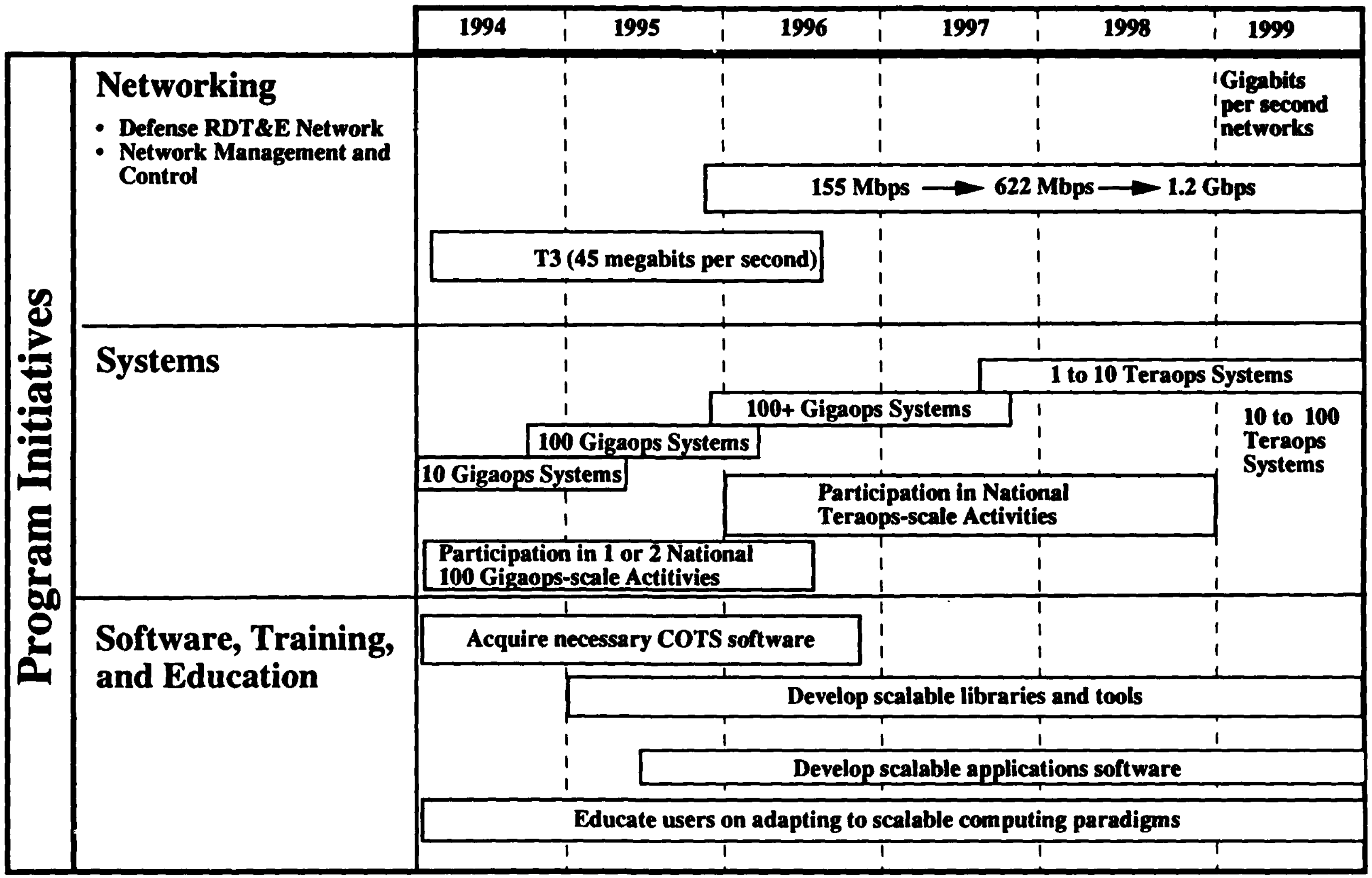

Figure 3. DoD HPC Modernization Plan Roadmap

The set of scalable parallel systems acquired or enhanced as part of the FY93 Implementation Plan represents, in the aggregate, over 200 GF-yrs of overall HPC performance available to DoD S&T users. This capability is a significant fraction of the total HPC requirements for FY94 (Tables 4 and 5). In addition, the Intel Paragon XP/S-25 operated at NCCOSC in a classified mode provides a substantial part of the 42 GF-yrs of classified S&T requirements, but not all classified users are capable of taking advantage of that particular architecture. Many of the scalable parallel systems implemented in FY93 lack adequate system peripherals and central memory to allow efficient use by multiple users.

Interim DREN has proven to be highly successful in allowing users at DoD user sites to access the HPC systems implemented in FY93. Key limitations include insufficient bandwidth to move large files created by some user applications and the slower transmission speeds available to classified users who must depend on end-to-end encryption devices.

The MOA with NCHPC has recently begun to bear fruit for DoD S&T users. The NCHPC collaboration groups have held initial meetings and begun to formulate plans for scalable software development efforts in each area. One indirect benefit of the NCHPC collaboration groups has been the incentive for internal DoD researchers within each technology group to meet and collaborate in ways that have not occurred previously. Several DoD research projects have made use of NCHPC computational resources that have allowed scaling problems to larger sizes than would have been possible on DoD HPC systems alone. To date, this added capability represents only a tiny fraction of the total DoD HPC S&T requirements, but further exploitation of NCHPC assets, based on the FY 92/93 investment, will allow unique opportunities for specialized DoD applications.

5.3 FY94 Efforts

An Implementation Plan has been developed in close coordination with the Services and S&T user community to apply available FY94 funds to immediate upgrades and expansions, to alleviate current saturation, and to make existing systems more effective. The DoD S&T community has significant requirements to solve research problems in the memory and compute intensive domain for which high performance computing is required. Table 6 indicates the HPC Center deployments that represent critical S&T requirements that can be addressed immediately through FY94 acquisitions. Deployments to each of these centers were judged using the criteria of S&T requirements, economic soundness management commitment, and information infrastructure. Execution of the plan will involve the use of both new and previously competed contracts and be in full compliance with Congressional direction for FY94. The Implementation Plan contains a system summary, rationale, acquisition plan, and funding allocation for each of the planned FY94 acquisitions. A similar Implementation Plan will be issued early each FY to provide like details for that FY's program execution.

Table 6. Summary of Planned FY94 HPC Systems

SITE	SYSTEM	FY94 ACTIONS
CEWES	C90	Upgrades to central memory, secondary storage, and archival storage
NAVO	C90	New Cray C916/1024
Army Research Lab	TBD	New scalable HPC system
ASC	Paragon	Upgrade to distributed memory and secondary storage
AFDTC	Cray T3D	New Cray T3D scalable system
MHPCC	IBM SP2	Upgrade of performance capability from 60 to 100 GF for unclassified system; upgrades to distributed memory and secondary storage
NCCOSC	Paragon SPP-1	Upgrade of distributed memory and secondary storage; addition of file archiving system Upgrade of distributed memory and other peripherals; additional processors
Naval Research Lab	CM-5 TBD	Upgrade to distributed memory and secondary storage; additional processors New scalable HPC system
Rome Lab	TBD	New scalable HPC system

In addition to addressing some specific local requirements detailed in the Implementation Plan, these FY94 actions address a broader base of requirements as summarized in Chapter 4 and as determined by initial experiences with systems implemented in FY93. Several existing systems, including the C90 at CEWES, the IBM SP2 at the MHPCC, the Paragons at NCCOSC and ASC, and the CM-5 at NRL, are having either central memory or peripheral storage upgraded to make those systems more efficient and effective for current and projected user bases. In each case, user requirements and experiences dictate that these enhancements are essential to continued efficient operations. In each of these cases, the initial FY92/93 investment provided the basic system, but it was realized at that time that FY94 upgrades would have to be made to complete a balanced system.

New capacity and capability is also a component of the FY94 actions. The addition of a new Cray C916/1024 and the conversion of the existing Y-MP/8 to classified DoD use at the Naval Oceanographic Office (NAVO) will further enhance DoD vector HPC capability, alleviate some of the oversubscription of existing systems at CEWES, allow more extensive "grand challenge" computations on these systems, and provide the first DoD vector HPC classified capability. All of these improvements in the ability to satisfy current user requirements are urgently needed.

New scalable parallel systems at AFDTC, ARL, NRL, and Rome Laboratory, with computational enhancements planned to existing scalable parallel systems at the MHPCC and NCCOSC, will add over 100 GF-yrs to the overall HPC performance available to DoD S&T users. When the enhancements are combined with the capabilities provided in FY93 and the new vector HPC capabilities at NAVO in FY94, the total performance capability available to DoD HPC researchers will be approximately 400 GF-yrs. This total represents 60 per cent of the total FY94 S&T requirements given in Tables 4 and 5.

5.4 Planned FY95 Efforts

To fulfill the goal of providing HPC capacity and capability, and to address the software issues in training and education required to effectively use the HPC resources, the program will continue its plans to establish DoD Major Shared Resource Centers (MSRCs) located within the Services and participating Agencies. The MSRCs will provide complete HPC environments and include various types of computing systems, scientific visualization capabilities, extensive peripheral and archival storage, and expertise in use of these systems. The MSRCs will support the wide variety of research and development problems arising from the science and technology programs supporting DoD's weapons development and warfighting support systems. The MSRCs will provide the computer and computational sciences expertise to allow all of the DoD laboratories to advance their capability in science and technology. The types of computer systems in the MSRCs will be determined by user requirements and may differ from one MSRC to another.

Actions to establish MSRCs are:

- The program has selected four sites to become MSRCs. Criteria for selection were based on R&D synergism, infrastructure, affordability, management commitment, and experience in serving remote users. The selected sites for MSRCs are:

  -- Army Corps of Engineers Waterways Experiment Station, Vicksburg, MS

  -- Naval Oceanographic Office, Stennis Space Center, MS

  -- Army Research Laboratory, Aberdeen Proving Ground, MD

  -- Aeronautical Systems Center, Wright-Patterson Air Force Base, OH

- In FY95 the program office is planning a full and open competition for acquisition of HPC capabilities, based on requirements of the users, to populate the MSRCs. The program anticipates multi-awards to teams including academe and industry, led by system integrators.

In addition to MSRCs, the program will continue to deploy systems to Distributed HPC Centers to fulfill special R&D requirements where the HPC systems are critical to success of S&T efforts and where special collections of HPC expertise can be leveraged for benefit of the entire program. Multiple systems will be acquired using several competitive acquisition vehicles.

Figure 4 depicts the DoD HPC laboratory modernization of both MSRCs and Distributed Centers. All functions are performed by the DoD HPC MSRCs. The shaded functions in the figure represent those functions expected of the Distributed HPC Centers.

In FY95 the program will initiate a full and open competition for acquisition of network services to provide OC3-level service (155 Mbps) to selected sites and minimum T3 (45 Mbps) service to all other DoD sites participating in the program. Award of a contract for DREN network services is planned for the third quarter of FY95. These services will replace the Interim DREN, which as described earlier, is comprised of dedicated leased circuits. Anticipated benefits include higher performance and improved cost effectiveness.

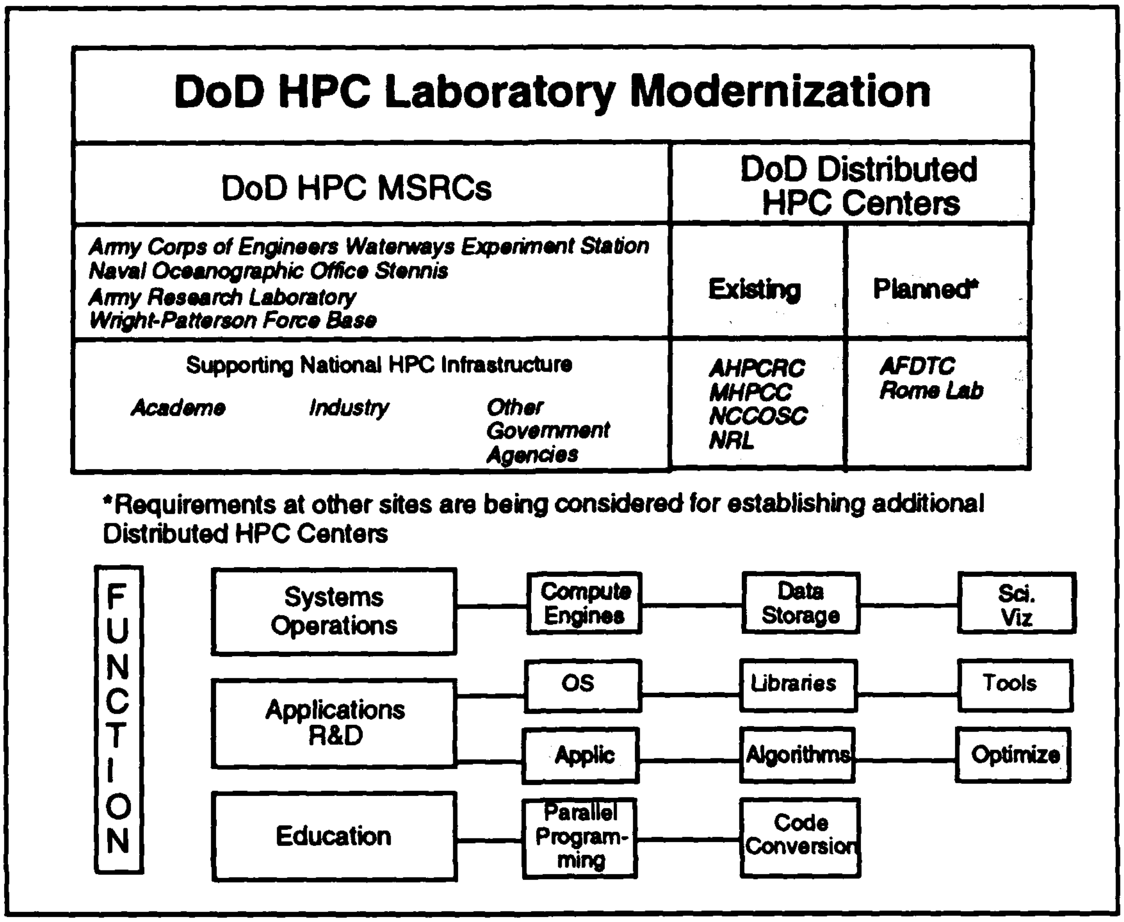

Figure 4. DoD HPC Laboratory Modernization

The program will leverage existing resources and university relationships for HPC capability, training, applications and algorithm development, and software tools. It will continue to coordinate with NCHPC to take advantage of available training through the NCHPC members, continue software collaborations, and make use of the NCHPC software repository and NCHPC scalable hardware. Finally, the program is also planning to implement an internal DoD scalable applications software initiative to enable DoD researchers to begin to overcome the software impediments to effective use of scalable HPC on DoD mission problems.

The summaries of classified and unclassified requirements in Tables 4 and 5 indicate an order of magnitude growth from FY94 to FY96. The planned FY95 activities, particularly those establishing and equipping the MSRCs, must put in place a large share of HPC systems and environments targeted to meet those FY96 needs. The total requirement of over seven TF-yrs will be difficult to meet with planned FY95 activities alone. Current projections indicate that the initial acquisitions for the MSRCs in FY95 could add several hundred additional GF-yrs to the available DoD capability, resulting in a total capability approaching one TF-yr.

5.5 Long Term Implementation Strategy (FY96-FY99)

- Continue to evolve and modernize MSRCs.
- Continue to acquire special systems for Distributed HPC Centers with critical requirements.
- Acquire adequate data storage capabilities at appropriate distributed centers.
- Evolve the network to gigabit per second (and beyond) performance levels to be consistent with the performance levels of the HPC systems, and as user requirements dictate.
- Develop mechanisms for creation of interdisciplinary teaming which leverages academe and industry expertise in HPC.
- Promote software tooling and scalable application and algorithm development initiatives.

If it is difficult to meet the FY96 S&T computational requirements, it is even more difficult to satisfy the projected FY99 computational requirements of 70 TF-yrs. These planned out-year actions are likely to result in a total DoD S&T performance capability of 20-30 TF-yrs. This level of capability would represent slightly less than half of the projected computational requirements.

5.6 Funding Needs

Table 7. Funding Profile ($M)

	FY94	FY95	FY96	FY97	FY98	FY99
MSRC Systems[1]	73.2	80.0	80.0	80.0	95.0	100.0
Distributed Center Systems[1]	49.1	40.0	40.0	40.0	55.0	55.0
Software, Appl Support, Education and Training Initiatives	0.8[2]	20.0	25.0	30.0	40.0	50.0
Networking	10.8	20.0	30.0	40.0	45.0	50.0
Program Management and Administration	3.0	3.0	3.2	3.4	3.5	3.8
Sustainment of Operations	6.9	20.0	32.9	44.0	49.8	55.0
TOTAL	143.8[3]	183.0	211.1	237.4	288.3	313.8

[1] These systems recognize that there are specialized requirements both mission and contractual (such as DNA's contractual requirements) which must be met by the HPC MP and provisions will be made to meet these needs

[2] Includes $0.8M COTS software

[3] Available funds after undistributed cuts ($146.1M appropriated)

6. Acronyms and Definitions

AFB	Air Force Base
AFDTC	Air Force Development Test Center
AHPCRC	Army High Performance Computing Research Center
algorithm	procedure designed to solve a problem
AMOS	Air Force Maui Optical Station
APG	Aberdeen Proving Ground
ARL	Army Research Laboratory
ARPA	Advanced Research Projects Agency
ASC	Aeronautical Systems Center
ASD	Assistant Secretary of Defense
ASW	anti-submarine warfare
CAA	Concepts Analysis Agency
C3I	Command, Control, Communications, and Intelligence
C4I	Command, Control, Communications, Computers and Intelligence
CEWES	Army Corps of Engineers Waterways Experiment Station
Computational Science Engineering	The systematic application of computing systems and computational solution techniques to mathematical models formulated to describe and simulate phenomena of scientific and engineering interest.
CPU	central processing unit
DDR&E	Director of Defense Research and Engineering
DNA	Defense Nuclear Agency
DoD	Department of Defense
DOE	Department of Energy
DREN	Defense Research and Engineering Network
FFRDC	Federally Funded Research and Development Centers

FY	fiscal year
GF	gigaflops
gflop	gigaflops
Grand Challenge	A fundamental problem in science and engineering with broad economic and scientific impact, whose solution can be advanced by applying HPC techniques and resources.
HBCU	Historically Black Colleges and Universities
Heterogeneous System	A distributed system that contains more than one kind of computer.
HPC	High Performance Computing
	Covers the full range of advanced computing systems including workstations, networks of workstations with servers, scalable parallel systems, vector parallel systems, and more specialized systems. Scalable input/output interfaces, mass storage systems, and archival storage are components of these systems. Included also are system software and software development environments that enable users to view their workstations and the rest of their computing environments as a unified system.
HPCC	High Performance Computing and Communications
HPCM	High Performance Computing Modernization
HPCWG	High Performance Computing Working Group
IDREN	Interim Defense Research and Engineering Network
Internet	The global collection of interconnected multi protocol computer networks.
LES	large eddy simulation
MHPCC	Maui High Performance Computing Center
MI	Minority Institutions
MOA	Memorandum of Agreement
MSRC	Major Shared Resource Center
NAVO	Naval Oceanographic Office
NASA	National Aeronautics and Space Administration
NCCOSC	Naval Command, Control and Ocean Surveillance Center

NCHPC	National Consortium for High Performance Computing
NRL	Naval Research Laboratory
NSF	National Science Foundation
NSWC	Naval SurfaceWarfare Center
NUWC	Naval Undersea Warfare Center
OGA	other government agency
ONR	Office of Naval Research
R&D	Research and Development
RDT&E	Research, Development, Test, and Evaluation
S&E	scientists and engineers
SRC	Shared Resource Center
S&T	science and technology
TBD	to be determined
TF	teraflops
WPAFB	Wright-Patterson Air Force Base